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Research Paper

Influence of weather parameters on rice false smut disease progression in Tamil Nadu, India

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ABSTRACT

False smut of rice is an upcoming menace to rice production in India. In order to understand the intricate relationship between disease incidence and weather parameters, field experiments were conducted for three years (2019, 2020 and 2021) in two cropping seasons *viz.,* late *kharif* (August to November) and *rabi* (October to January) at the Agricultural College and Research Institute (AC & RI), Madurai, Tamil Nadu. Results revealed that the disease severity had positive correlation with relative humidity (RH), wind speed (WS) and bright sunshine hours (BSS) and negative correlation with heavy rainfall (RF), evaporation (EP) and temperature. The pooled data analysis (2019 and 2020) for the late *kharif* and *rabi* cropping season revealed that disease severity was perfectly showed positive correlation with relative humidity (0.80) and wind speed (0.83) and negatively correlated with weekly maximum temperature (-0.78) and minimum temperature (-0.84). The step wise linear regression analysis was performed which revealed that among the six weather factors minimum temperature influenced the false smut disease severity up to 92%.

Keywords: False smut, disease severity, correlation, late *kharif, rabi*.

Rice (*Oryza sativa* L.) is one of the most important grain crops and it plays a key role in reducing the starvation of millions of livelihoods in the present and future of the world. Rice is easily affected by various biotic and abiotic stresses, resulting in poor productivity and quality. Among the various biotic stresses, rice false smut caused by *Ustilaginoidea virens* (teleomorphic state -*Villosiclava virens*) is the most important grain disease which not only reduces the yield but also deteriorates the quality due to the production of mycotoxins such as ustiloxins and ustilaginoidins (Baite and Sharma, 2015).

The edaphic and environmental factors such as high rainfall, high humidity, high wind speed and soil with high nitrogen content, favor the growth and development of *U. virens* causing significant increase in disease severity. Rice false smut was once considered as a minor and of late it has become one of the major

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diseases in most of the rice-growing of the world. The main reason is due to the widespread cultivation of high-yielding varieties, high application of nitrogenous fertilizer and climate change (Zhou *et al.,* 2008). The range of disease incidence varies from 4.8% to 55.6% depending upon rice genotype and climatic conditions (Baite *et al.,* 2017). Currently, this disease has gained importance because it causes yield loss of about 0.5% to75% depending upon favourable weather conditions prevailing during the flowering stage of the crop (Singh and Dube, 1978). The rate of disease progression is high during conducive environmental conditions such as high humidity (>80%), intermittent rainfall during the flowering stage and temperatures ranging from 25˚C to 30˚C (Yashoda *et al.,* 2000). Yashoda *et al.,* (2000) optimized the chlamydospore spray during flowering stage had resulted in highest severity of false smut disease (20%). The maximum false smut disease incidence was noticed during flowering time overlapped with scanty and drizzling rainfall (Mandhare *et al.,* 2008). (Baite *et al.,* 2021) reported that a moderate evaporation combined with high relative humidity (74-82%) predisposes the false smut infection during the flowering stage of the rice crop.

The successful management of rice false smut disease requires thorough knowledge on pathogen's spread and epidemiological parameters favoring its development. The quick management of any plant disease is achieved by application of fungicides. However, the constant and repeated application of fungicides leads to the development of resistance against the fungicides over a period of time.

Under these circumstances, one of the best options available is the use of biocontrol agents which are environment friendly. However, the main disadvantages of using biological control agents are its slow effect in suppressing the pathogen compared to the fungicide and it's non-availability to the farmers when needed. Alternatively, the study on the conducive epidemiological factors which favors false smut disease development is also helpful not only to avoid the conjunction of the flowering stage with favorable environmental conditions but also to predict the disease occurrence in advance and thereby the need-based fungicide spray can be undertaken to manage the disease effectively. Hence, this type of method of management is also effective.

MATERIALS AND METHODS

Field experiments were conducted for three years (2019, 2020 and 2021) in two cropping seasons *viz.,* late *kharif* (August to November) and *rabi* (October to January) at the Agricultural College and Research Institute (AC&RI), Madurai for the late kharif and rabi cropping seasons the varieties BPT 5204 and TKM 9 respectively were used. These varieties were grown in major rice growing regions in Madurai district of Tamil Nadu. The respective rice variety, BPT 5204 was sown in the nursery and 30 days old seedlings were transplanted in field plots (2.5×2.5 square meter) at a spacing of 20×15 cm. Standard agronomical practices were followed every year for proper crop establishment. The disease severity was recorded at weekly intervals from ten plants were randomly selected in each plot within a field following Standard Evaluation System (SES) scale (IRRI standard). The meteorological readings were taken during the flowering period when the false smut spores start to disperse.

To determine the influence of various meteorological variables on the development of rice false smut, the disease severity was correlated with different weather parameters *viz.,* rainfall (mm), weekly maximum temperature (^{0}C), weekly minimum temperature (^{0}C), relative humidity (%), bright sunshine hours, wind speed (km/s) and evaporation (mm). The weather parameters were obtained from the Agrometeorological observatory maintained by Department of Agronomy, Agricultural College and Research Institute, Madurai affiliated with Tamil Nadu Agricultural University, Coimbatore

Disease observations

Weekly observations on disease development were recorded from panicle initiation to grain filling phase. Percent infected panicles, percent infected spikelets and percent disease severity were calculated as per the formulae given below (Mandhare *et al.,* 2008; Singh and Dube, 1978). The disease severity values were taken for correlation analyses.

Percent disease severity = Infected panicles (%) × Infected spikelet (%).

The disease incidence on both panicles and spikelets were recorded after the panicle emergence (42nd Standard Meteorological Week (SMW) and grain filling stage (48th SMW) of late *kharif* (July to November). Similarly, the disease incidence was recorded at *rabi* (October – January) cropping season between 50th SMW to fourth standard week of the succeeding calendar year. The disease incidence was measured between growth stages of rice crop such as ear head emergence and grain filling stages because the *U. virens* infects only the inflorescence. During these growth stages between ear head emergence and grain filling stages the spikelets remained open during anthesis time. Through that gap, air-borne spores of *U.virens* will fall on stigma, and it start to produce a white smut ball at either side of the spikelet. Once the grain filling stage begins, the disease development was ceased due to the non-availability of space for spore landing

Analysis of data

Data were analyzed using IBM SPSS statistical software. Effect of different meteorological parameters on disease severity was determined by correlation analyses. Effect of different meteorological parameters viz. weekly maximum temperature (Tmax), weekly minimum temperature (Tmin), relative humidity (RH), bright sunshine hours (BSS), total rainfall (RF) and wind speed (WS) on disease severity was determined by correlation analysis. Weekly weather parameters and false smut disease severity were recorded at standard meteorological week from 42nd (20th October) and 48th (1st December) in late *kharif* cropping season and from 50th standard meteorological week (December 15) to 4th standard meteorological week (26th January). False smut disease prediction model was developed based on pooled severity index data (2019 and 2020) and meteorological parameters using step wise linear regression analysis and was validated using meteorological data of 2021 season.

Table 1: Assessment of disease severity and weather parameters recorded during late kharif and rabi season in different years

Sr. no	Weather parameters	*Late kharif* (Oct. 20 to Dec.1)			*Rabi* (Dec. 15 to Jan. 26)		
		2019	2020	2021	2019	2020	2021
1	Maximum temperature (Tmax, ⁰C)	35.7	33.6	31.6	32.3	30.5	31.9
2	Minimum temperature (Tmin, ⁰C)	21.3	21.3	21.5	20.9	20.7	16.1
3	Relative humidity (%)	75.1	78.5	84.5	77.6	80.4	86.2
4	Rainfall (mm)	4.0	7.9	12.0	0.3	5.4	4.8
5	Bright Sunshine (hours)	5.6	4.3	6.6	5.3	5.7	6.5
6	Wind speed (km/s)	23.5	5.1	6.6	11.4	9.7	7.5
7	Disease severity (%)	12.30.7±	22.31.5±	25.3±1.7	10.5±0.6	14.6±0.8	28.9±1.9

*Values are means of three replications ± indicates standard deviation

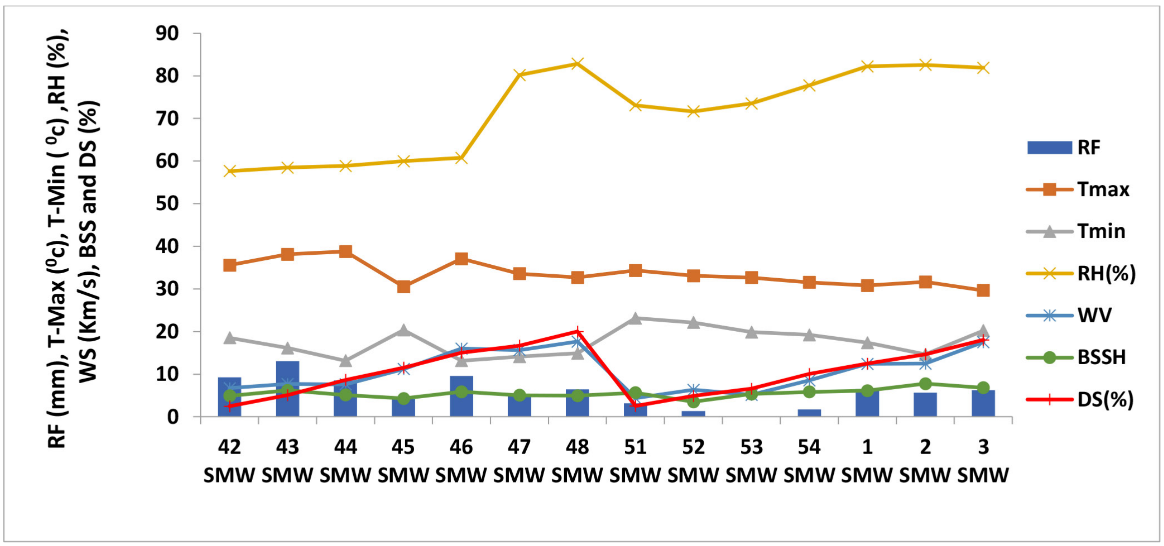

Fig. 1: Three years mean weekly weather data and disease severity (late *kharif* and *rabi* cropping season)

RESULTS AND DISCUSSION

Weather and disease progression during seasons

Fig.1 depicts the weekly mean weather data and disease severity during both the seasons (late *kharif* to *rabi*) averaged over all the three years. Relative humidity was found to increase with the season, while maximum and minimum temperatures were found to decrease. The disease severity also increased during both the seasons. The seasonal mean data presented in Table 1 show that the all the weather parameters varied between the two cropping seasons as well as among the years. As a result, the disease severity also varied across the season and years. During late *kharif* season, the mean disease severity was 12.30.7%± in 2019, 22.31.5%± in 2020 and 25.3±١.7% in 2021. Similar increasing trend was observed during *rabi* season also (Table 1).

Correlation between weather parameters and disease severity

The correlation worked out between different weather parameters and disease severity in two seasons for individual years and with pooled data are presented Table 2. The results revealed that the maximum and minimum temperatures had negative correlations while relative humidity, wind speed and sunshine hours had positive correlation in both the season as well as in individual years and in pooled analysis (Table 2). The pooled analysis revealed that the disease severity was negatively correlated with maximum and minimum temperature with -0.96 and -0.87 respectively which indicated that the disease progression was significantly decreased by increasing both maximum and minimum temperature. Jiehui *et al.,* (2021) also reported that the incidence of rice false smut was significantly correlated with average temperature at fortnight intervals after ear head emergence. This finding supported the approach of this study on designating the influence of temperature during the smut ball formation as it was the important indicator for increasing the disease severity in rice.

The disease severity was positively correlated with relative humidity, wind speed and bright sunshine hours at 0.88, 0.97 and 0.60 respectively. Additionally, many researchers have found a positive relationship between high relative humidity and false smut disease development (Pal *et al.,* 2017; Jeena *et al.*, 2022). Earlier studies showed that BSS in association with optimum RH (70-80%) encouraged good crop growth as well as rice false smut disease development (Sandhu *et al.,* 2017). From these findings, we can clearly understand the good relationship between disease severity and wind speed, where an increase in wind speed positively

Table 2: Correlation coefficients between weather parameters and the disease severity

Weather parameters	Late *kharif*			*Rabi*			Pooled data (Late *kharif* & *rabi*)
	2019	2020	2021	2019	2020	2021	
Tmax	-0.83	-0.93*	-0.87	-0.87	-0.6	-0.92	-0.96
Tmin	-0.87	-0.76	-0.81	-0.86	-0.87	-0.88	-0.87
RH	0.9	0.94	0.91	0.95*	0.69	0.94*	0.88
RF	-0.36	-0.46	-0.65	-0.51	0.88*	0.59	-0.28
BSS	0.19	0.77	0.96*	0.15	0.62	0.92*	0.60
WS	0.88	0.69	0.92	0.89	0.88	0.93	0.97

* indicates correlation is significant at 0.05 level

correlated with disease progression during the anthesis period. Because the spores are carried to healthy plants from the infected plant through wind, the disease incidence is higher levels under windy period. Our present results were also in agreement with reports of earlier studies which showed that wind speed was an important factor for the false smut disease distribution (Baite *et al.,* 2017).

The weak negative correlation was observed between disease severity and rainfall at -0.28 indicated that heavy rainfall obstructs the disease development but slight drizzles favor the disease progression. It is assumed that the heavy rainfall prevents the spore dispersal. From the above findings, it was observed that the heavy rainfall did not create any significant impact on rice false smut disease development. Thus, the disease severity was quite higher in the *rabi* cropping season compared to that in late *kharif* season. Similarly, the earlier studies also reported that heavy rainfall did not influence the disease development and showed a negative correlation between rainy days and disease incidence (Alase *et al.,* 2021).

Calibration and validation of regression model

Using pooled data of disease severity for the three years (2019, 2020 and 2021) in both the cropping seasons (late *kharif* and *rabi*), the multiple linear regression analysis was performed to estimate the prediction model equation of false smut infection in terms of percentage as detailed below;

Y= 279.557- 3.761 (Tmax) - 4.573 (Tmin) + 0.016 (RH) + 1.968 (RF) -13.375 (BSS) + 0.137 (WS)

(R^2=0.991)

where, Y= false smut disease severity percentage.

The developed equation was then validated with late *kharif* and *rabi* cropping seasons during 2021 meteorological data, which showed 0.96-1.82% and 0.36-4.87% variability respectively. The observed and predicted disease severity values (all the three years in both the cropping season) revealed that 92.1% percent variation of disease severity (dependent variable) as explained by independent variable (Fig.2). In order to limit the variables, step wise linear regression analysis was performed which revealed that among the six weather factors minimum temperature influenced the false smut disease severity up to 92% (R^2). Most of the paddy varieties flowering period varied from 7 to 21 days. Since this pathogen is highly organ specific prophylactic fungicidal spray can be recommended when the precipitation reached beyond 9.79 mm, the minimum temperature is less than 27^{0}C, relative humidity more than 94%, critical wind speed 8.90m/sec, minimum Bright sun shine hours 7.75 hours prevailed during the first week of flowering phase.

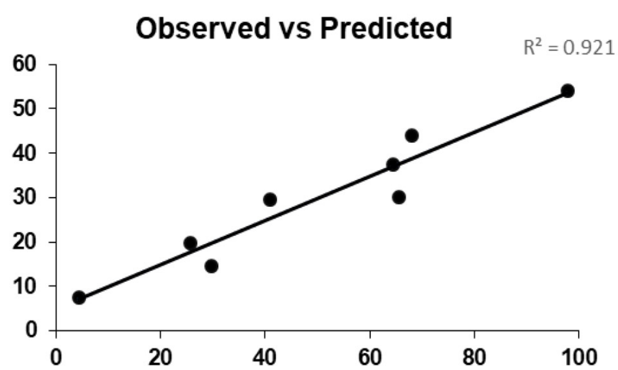

Fig. 2: A comparison of observed and predicted disease severity values.

CONCLUSION

The present research revealed that the progression of rice false smut disease was increasing gradually and expands its infection foci in a selected experimental unit at Agriculture College and Research Institute (AC&RI), Madurai. In all the years of both the cropping season relative humidity increase positively influence the disease development. The present findings revealed that a strong relationship existed between disease severity and various weather parameters *viz.,* temperature, relative humidity, drizzling rainfall, evaporation and bright sunshine hours. Among the weather parameters, relative humidity, temperature and wind speed were the important factors that greatly influenced the disease severity in both late kharif and rabi cropping seasons. To avoid the false smut infection in rice, sowing of rice should be manipulated in such a way as to skip the flowering period during critical months of infection (October to mid-November in late *kharif* cropping season and December to mid-January in *rabi* cropping season).

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